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When to Perform Antenna Measurements in a Near-Field Range or a Short Tapered Chamber

by Theodore K Anthony

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When to Perform Antenna Measurements in a Near-Field Range or a Short Tapered Chamber

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Contents

List of Figures	iv
1. Introduction	1
2. Decision Tree Parameters	1
3. Decision Tree Questions	2
4. Antenna Theory	3
5. Near-Field Range	4
6. Tapered Anechoic Chamber (Far-Field Range)	4
7. Conclusion	7
8. References	8
List of Symbols, Abbreviations, and Acronyms	9
Distribution List	10

List of Figures

Fig. 1	Fields from a radiating antenna (image courtesy of Nearfield Systems, Inc.)	3
Fig. 2	NFR/FFR decision tree	5
Fig. 3	Venn diagram shows the best antenna range given conditions.....	6

1. Introduction

This study was undertaken to quantify and compare electromagnetic (EM) device (i.e., antenna) measurements using the US Army Research Laboratory's (ARL) near-field range (NFR) and tapered anechoic chamber. Our 2 antenna measurement systems obtain similar results, as reported in a previous ARL technical report, *A Comparison of Antenna Measurements in a Near-Field Range and a Newly Renovated Short Tapered Chamber*,¹ but a decision tree was requested to obtain the results for future antennas under test (AUTs) in the most cost-effective manner (man-hours, custom mounting, etc.). The NFR and tapered anechoic chamber are the basic resources that the antenna team can use to measure and characterize EM fields that are transmitted and/or received by devices (e.g., antennas) to validate simulated performance with measured data. Accordingly, it was imperative that a decision tree mapping out the most cost-effective manner to obtain AUT data be established for either the NFR or tapered anechoic chamber.

The NFR can obtain planar, cylindrical, or spherical near-field measurements of EM fields, while the tapered anechoic chamber can obtain spherical far-field pattern measurements of EM fields. Our NFR has a frequency range of 1.2–50 GHz with maximum internal chamber dimensions of $25 \times 16 \times 10$ ft, while the tapered anechoic chamber has a frequency range of 0.2–50 GHz with chamber dimensions of $20 \times 20 \times 55$ ft.

2. Decision Tree Parameters

Deciding when to use either the NFR or the tapered anechoic chamber, also named the far-field range (FFR), is a complex process. Fortunately, the information needed for this decision can be obtained, but compromises might need to be made for speed, resolution, and setup costs. The most important decision parameters of interest are the customer's output requirements. More decision parameters are the AUT's characteristics such as weight, dimensions, and directivity. These parameters, along with time frame and funding level, determine if there is a need for phi axis AUT custom mounting.

The customer's output requirements can include frequency range and resolution, angular range and resolution, polarization, 3-D and 2-D radiation patterns, and boresight realized gain. The customer's output requirements will navigate most of the route on the decision tree. The AUT's weight, dimensions, and directivity will then narrow the decision tree parameters further, taking you to the final turn. Finally, a decision has to be made if the data collection process needs to be sped up by crafting a phi axis custom mount for the AUT.

3. Decision Tree Questions

This decision tree process is mostly yes/no answers to questions based on the information on hand. The following are a few questions to ask, with the decision and reason in parentheses:

- When must you get this data by? (Helps to set priority level, and sets the bound for the most that could possibly be done.)
- Does the AUT only transmit through its own source? (If yes, the FFR is best suited for this measurement since the NFR would be harder to convert for this type of measurement.)
- Are any of the frequencies of interest below 1.2 GHz? (If yes, only the FFR [0.2–50 GHz] can measure below 1.2 GHz. The NFR measures from 1.2 to 50 GHz.)
- Do you only need boresight realized gain? (If yes, only the FFR can measure just the boresight realized gain. The NFR requires measuring a great portion of the AUT's radiation surface energy [3-D] to calculate the AUT's gain.)
- Is $f_{\text{MAX}}[\text{GHz}] > 19.685/(D[\text{feet}])^2$, where D is the diagonal across the AUT's aperture? (If yes, only the NFR can measure this AUT since this is considered a near-field measurement.)
- Is the AUT's front to back ratio worse than 10 dB? (If yes, only the FFR can measure this AUT since the NFR's back plate will corrupt the data without reflection mitigation.)
- What are the AUT's dimensions and weight? (The FFR is more accommodating than the NFR in that it has more space to maneuver large AUTs and the ability to spin over 5000 N on its turntable.)
- Would the AUT's torque on the phi axis plate be greater than 60 N-m? (If yes, the FFR is best suited for this measurement since the NFR cannot withstand as much torque as the FFR.)
- Do you need 3-D radiation patterns? (If yes, a phi axis custom mount for the AUT needs to be crafted for the NFR, or a Styrofoam cylinder or sphere needs to surround the AUT under test centered along the AUT's phi axis for the FFR.)
- Is there going to be a phi axis custom mounting for the AUT? (If no, the FFR is best suited for this measurement since the NFR cannot cover 330° without a phi axis custom mount.)

- Do you only need 2-D radiation patterns? (If yes, only the FFR can measure just the 2-D radiation patterns. The NFR requires measuring a great portion of the AUT's radiation surface energy [3-D] to calculate the AUT's 2-D radiation patterns.)

4. Antenna Theory

For the purposes of testing in the NFR, the antenna must be situated in the radiating near-field for proper data acquisition. The antenna has a reactive near-field from 0 to λ with a fairly flat field distribution, where objects in this region can possibly cause unwanted coupling to the antenna. As such, near-field systems cannot measure inside this region due to the unknown coupling effects to an AUT. The radiating near-field is from λ to $2D^2/\lambda$ with a fairly smooth field distribution, where D is the largest dimension across the aperture.³ Near-field systems measure inside this region. The far-field region is next, extending beyond $2D^2/\lambda$, where most antenna chamber measurements are done. Figure 1 shows the fields from a radiating antenna.

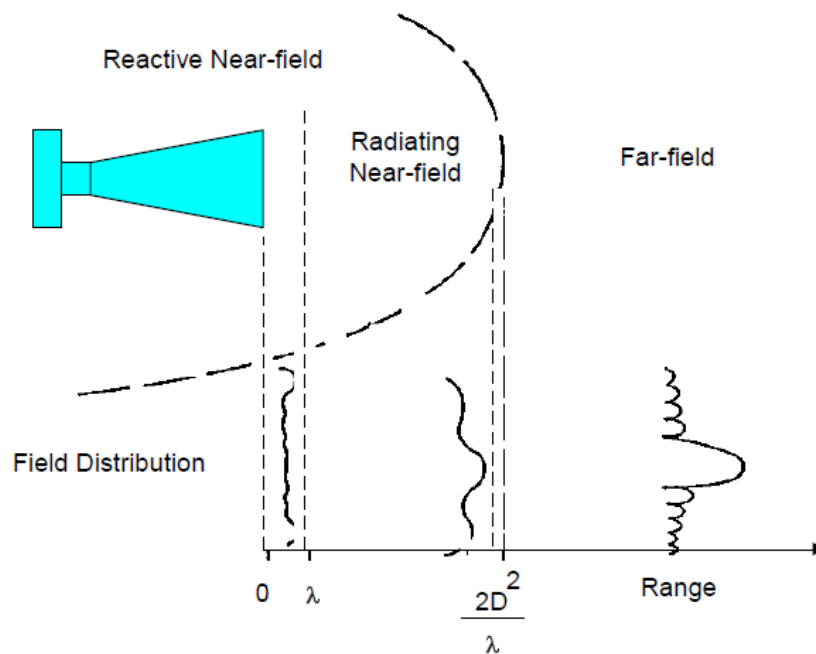


Fig. 1 Fields from a radiating antenna (image courtesy of Nearfield Systems, Inc.²)

The theory behind near-field measurements was developed at the National Institute of Science and Technology (NIST) in the 1970s by the Technical University of Denmark and NIST. NIST has validated the mathematical calculation of far-field patterns based on amplitude and phase samples in the radiating near-field.

5. Near-Field Range

The near-field planar measurement system is best suited for characterizing highly directive antennas or arrays because less than a hemisphere (spanning $180^\circ \times 180^\circ$) of energy can be measured with a planar scan. The AUT is positioned 3–5 wavelengths away from the planar scanner, hampering any wideband characterization without relocating the AUT. In addition, the hemisphere transitions to a narrower cone measurement as the test frequency lowers, thereby reducing the angular span of the measurement. The planar NFR uses waveguide probe antennas (7 antennas cover 1.1–18 GHz) with no AUT slide or removable mast and can measure mid- and small-sized AUTs. A single planar scan requires about 1 h of acquisition time for each waveguide probe measurement. No 2-D far-field patterns can be produced until a full planar near-field measurement is completed.

The near-field spherical measurement system can be used for characterizing antennas or arrays and can measure EM fields spanning $330^\circ \times 180^\circ$ of a sphere on a single setup. For this measurement the AUT should be placed above the azimuth positioner's center of rotation while centered along the phi positioner's center of rotation. The spherical NFR uses waveguide probe antennas (7 antennas cover 1.1–18 GHz) with no AUT slide or removable mast and can measure mid- and small-sized AUTs. A single spherical scan can require 2–72 h depending on wavelength and antenna positioning. Two-dimensional far-field patterns cannot be produced until a full spherical near-field measurement is completed. Therefore, spherical near-field measurements are better than planar for this comparison study with the tapered anechoic chamber.

6. Tapered Anechoic Chamber (Far-Field Range)

ARL's tapered anechoic chamber spherical measurement system can be used for characterizing antennas or arrays and can measure EM fields spanning $360^\circ \times 180^\circ$ of a sphere. It can measure a single point to determine realized gain, angular sweeps for 2-D pattern cuts, circular polarization, and 3-D patterns. The AUT should be placed above the azimuth positioner's center of rotation while centered along the phi positioner's center of rotation. The chamber uses decade calibration antennas (2 antennas cover 0.2–18 GHz) and has an AUT slide with removable mast, allowing measurement of large and small AUTs. A single 3-D spherical scan will take 3 h for 1–18 GHz, but a 2-D cut plane takes about 5 min. Figure 2, a decision tree, and Fig. 3, a Venn diagram, map out the most cost-effective manner to obtain AUT data from either the NFR or FFR.

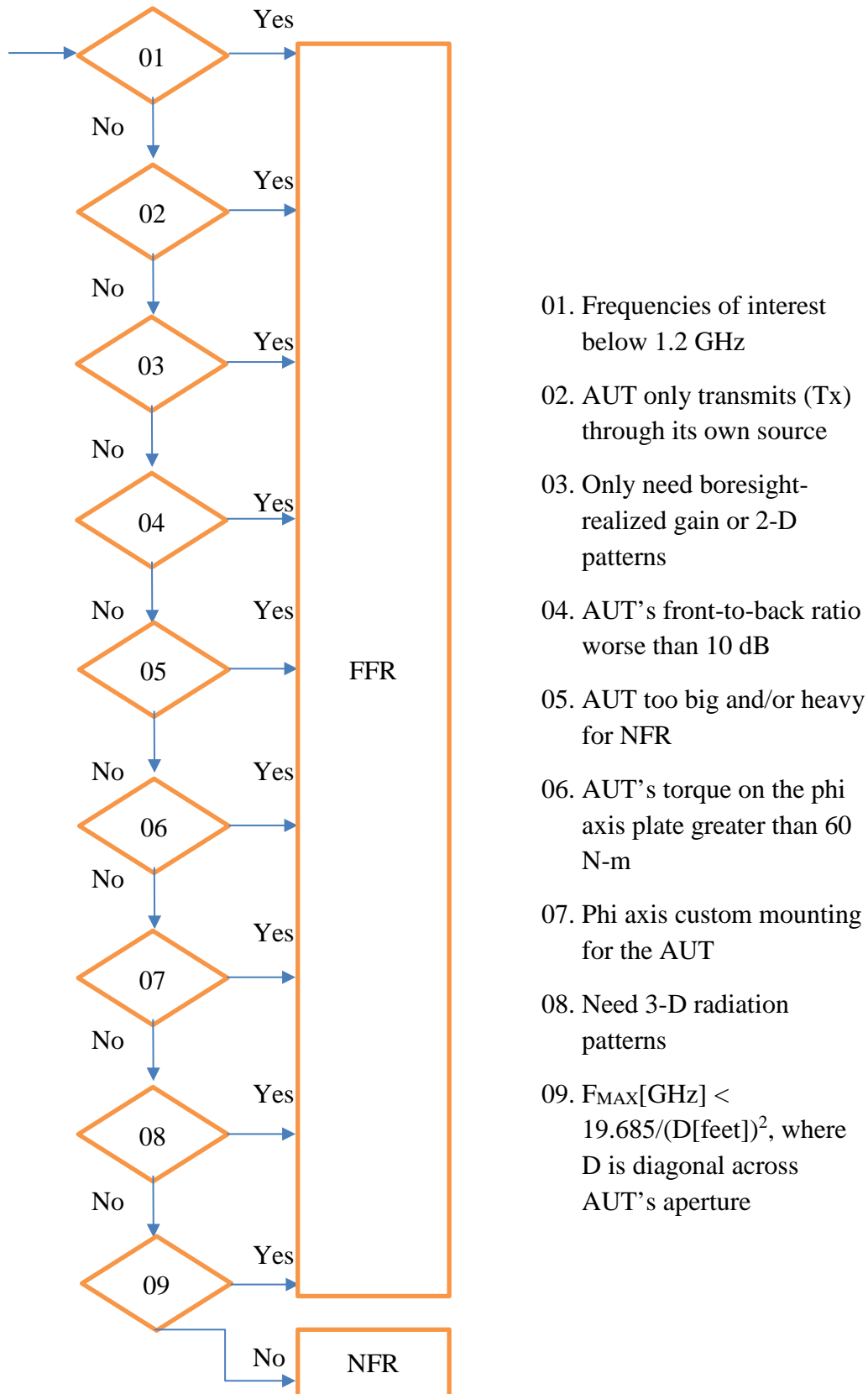


Fig. 2 NFR/FFR decision tree

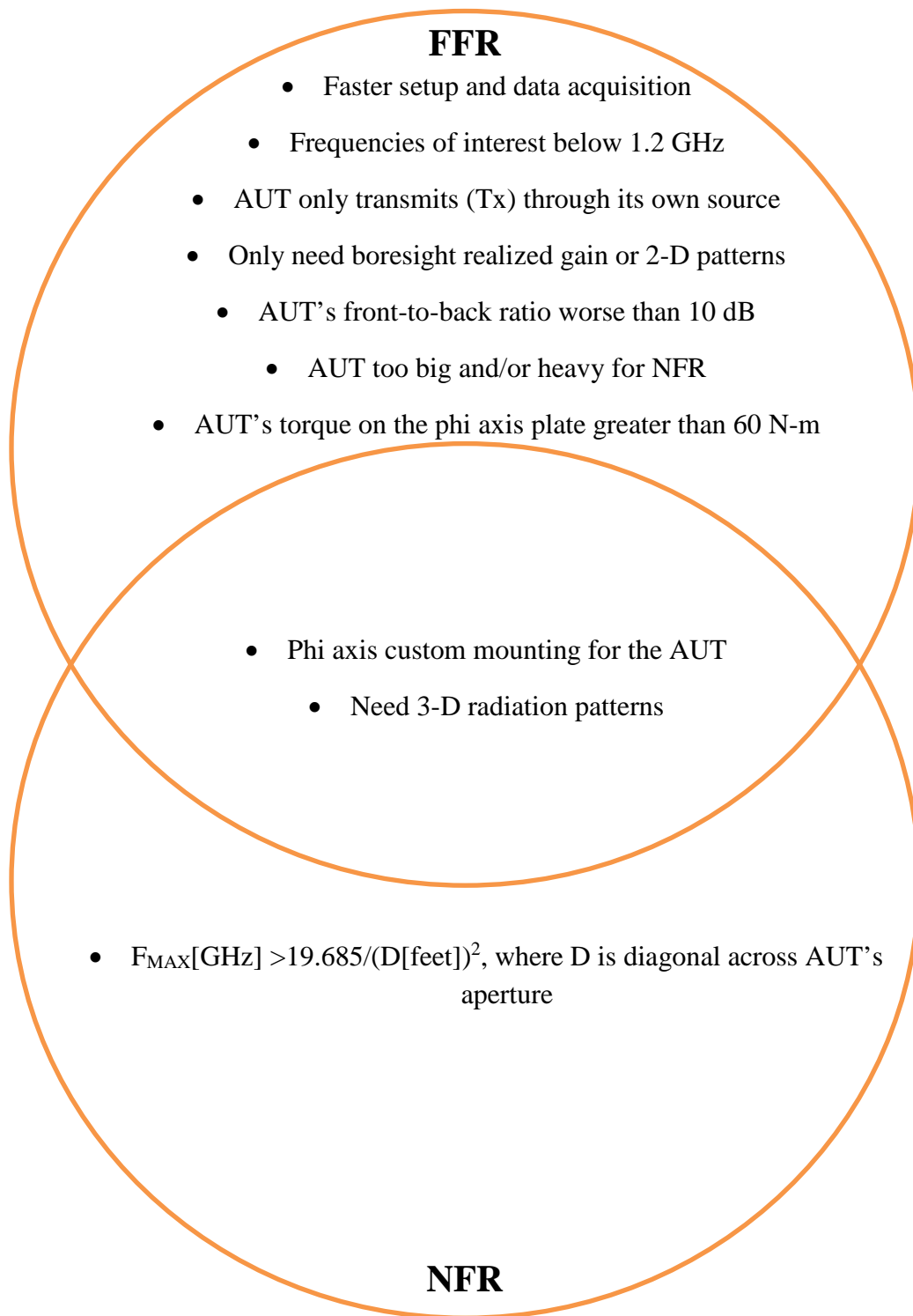


Fig. 3 Venn diagram shows the best antenna range given conditions.

7. Conclusion

This study was initially motivated to further validate our EM device measurements. Then a decision tree, mapping out the most cost-effective manner to obtain AUT data from either the NFR or FFR, was requested. Both systems measure patterns well, but each system has its own unique capabilities. Pattern and gain measurements are done quickest over a wide frequency range in the tapered anechoic chamber. The tapered anechoic chamber can also be used to find an antenna's phase centers. The NFR is best suited to produce far-field patterns from measured near-fields of antenna arrays and finding EM leakage with its NSI software tools. ARL's planar near-field measurement system requires the AUT to have a gain greater than 15 dBi, while a spherical near-field measurement only requires the AUT minimize radiation toward the phi positioner's metal mounting plate.

The initial study proved that the tapered anechoic chamber and NFR do provide comparable results, which further validates our EM device measurements. In addition, the highly detailed antenna range decision tree was successfully developed, clarifying when to use either the NFR or FFR for a given AUT.

8. References

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List of Symbols, Abbreviations, and Acronyms

2-D	2-dimensional
3-D	3-dimensional
ARL	US Army Research Laboratory
AUT	antenna under test
EM	electromagnetic
FFR	far-field range
NFR	near-field range
NIST	National Institute of Science and Technology

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